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ABSTRACT

Investigators in this study looked for conditions that can rapidly establish continuous stimulus control of continuous response variations, or "response mapping." Unlike previous research in stimulus control, where a single stimulus comes to control a single response, 36 5-year-old children received errorless discrimination training at three points along a circle-to-ellipse continuum following one of two different pretraining conditions which showed no difference in later acquisition. They were then tested on two stimuli intermediate between two of the training stimuli. Subjects were divided into two test groups and tested under conditions in which (1) the correct response bore a spatial relationship to the ordering along the continuum, or (2) the spatial location of the correct response key bore a constant but unordered relation to the stimuli. Subjects learning the ordered test acquired the new test responses faster than those in the unordered condition. Discussion of the results considered the effect of discrimination training, the errorless procedure, and response-produced feedback. (Author/SB)

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ESTABLISHING A CONTINUOUS REPERTOIRE

PAMELA MEADOWCROFT AND JAMES G. HOLLAND

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Abstract

Unlike previous research in stimulus control, where a single stimulus comes to control a single response, this study looked for conditions that can rapidly establish continuous stimulus control of continuous response variations, or "response mapping." Five-year-old children received errorless discrimination training at three points along a circle-to-ellipse continuum following one of two different pretraining conditions which showed no difference in later acquisition. They were then tested on two stimuli intermediate between two of the training stimuli. Subjects were divided into two test groups and tested under conditions in which (a) the correct responses bore a spatial relationship to the ordering along the continuum, or (b) the spatial location of the correct response key bore a constant but unordered relation to the stimuli. Subjects learning the ordered test acquired the new, test responses faster than those in the unordered condition. Discussion of the results considered the effect of discrimination training, the errorless procedure, and response-produced feedback.

ESTABLISHING A CONTINUOUS REPERTOIRE

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Many natural behaviors involve the control of a response continuum by a stimulus continuum. For example, to the artist a person's face is a complex continuum of light and lines which controls the continuous movement of the artist's brush. The extent to which the artist can distinguish the subtle changes in light that make up facial contours determines the likeness of the portrait to the model's face. For every discriminated line and subtle change of light, there is a corresponding brush stroke which will mirror this stimulus. Playing tennis is another example of a continuous relationship between stimuli and responses. The position of an opponent's body is the controlling stimulus for the tennis player's own body position. Slight changes in the opponent's position control movements of the player. When behaviors like these show progressively different responses in proportion to progressively different stimuli, then there is a continuous repertoire of behavior (Holland & Skinner, 1961). Drawing from a copy, handwriting, playing the violin, singing on key, riding a bicycle, and many other motor behaviors require continuous repertoires for accurate performance.

As commonplace as these kinds of behaviors are, we have seldom attempted an experimental analysis of their development. Instead, research in stimulus control typically confines the response to a single topography, while research in response variability leaves the stimulus conditions unvaried. The few studies that do measure changes in

response topography as a function of stimulus change typically train a few responses from a response continuum to a few stimulus points from a stimulus continuum (Boakes, 1969; Herrnstein & van Sommers, 1962; Migler, 1964; Wildemann & Holland, 1972). After this training, stimulus values intermediate to the training ones are expected to evoke intermediate responding without the intermediate responses themselves being reinforced. In other words, training fairly gross continuous control of stimuli over grossly different responses should generalize to similar stimuli and responses. This generalization would result in finer stimulus control of more subtly varying responses.

However, close examination of this research shows no emergence of true intermediate responses and, therefore, no evidence for the emergence of a finer continuous relationship between stimuli and responses. Some apparent intermediate responding merely reflects a combining of trained responses that, when averaged, shows an artifactual intermediate response (Herrnstein & van Sommers, 1962; Migler, 1964). For example, rats were trained in the presence of a slow clicking noise to switch from one bar to another after a 6-second delay; while in the presence of a fast click rate, they were trained to press the two bars with no delay (Migler, 1964). During tests with intermediate click rates, the average response delay was between the 6-second delay and no delay. However, a close look at each test trial showed only one or the other training delay so that the overall intermediate delay was an artifact of averaged data. Other apparent evidence for finer mapping of responses to a stimulus continuum after training only a few stimulus and response points is questionable because of the possible effects of stimulus dynamism (Boakes, 1969). Rats again were trained to press two bars at various delays for different intensities of light, after which intermediate test intensities were presented. Appropriate intermediate response delays did emerge, but only when the brighter stimulus values corresponded to shorter delays between bar presses. When

fast responding or short delays were reinforced during dimmer stimulus values, novel, intermediate stimuli failed to show the emergence of corresponding intermediate response delays. Thus, the apparent intermediate response delays were a function of a relationship between stimulus intensity and speed of responding and not due to the development of a continuous repertoire. One study with unequivocal results trained several response positions on a continuous long key to several tones, and, controlling for any peculiar stimulus dynamism effects and without averaging responses, the results showed no intermediate responding in the presence of intermediate tones (Wildemann & Holland, 1972). In general then, the simple training of a few stimulus and response points is not sufficient to condition a continuous repertoire, that is, finer continuous stimulus control than that which is trained.

But it is not surprising that finer variability in responding does not emerge since during the above training procedures any response intermediate to the training responses undergoes extinction which may offset any tendency for intermediate stimuli to evoke intermediate responses during testing. Moreover, since the typical training procedure requires extensive training, responses are effectively anchored to trained topographies; that is, stereotyped responding is enhanced. Some research suggests that an errorless procedure, which trains a discrimination rapidly (Moore & Goldiamond, 1964; Powers, Cheney, & Agostino, 1970; Terrace, 1972; Touchette, 1971) could reduce this anchoring (Cohen, 1967). With rapid training and the reduction of extinction through an errorless training procedure, more response variability may occur which would increase the possibility of experimentally demonstrating a continuous repertoire. But there is no literature or theoretical basis to presume variations from training responses would come under the control of nontrained stimuli without further training. On the contrary, the evidence to date suggests that values from a stimulus continuum come to control corresponding

responses only after extensive point-by-point training. However, this slow conditioning is not characteristic of the apparent rapid acquisition of continuous repertoires in the natural environment. It seems most unlikely that each slight move of a pencil in producing a pattern or a letter undergoes such extensive training. With this apparent rapid acquisition in mind, an experimental look at continuous repertoires should abandon testing new stimuli in extinction. Instead, new stimulus and response correspondences from the training continua should continue to be reinforced. The ease of learning these new stimulus and response points under various conditions would teach us much about the development of continuous relations between stimulus and response dimensions.

In speculating on the rapid learning of a continuous repertoire, Holland and Skinner (1961) emphasized the role of comparing response-produced stimuli (feedback) to stimulus values from the experimental continuum for quick, automatic, differential reinforcement so that any additional stimulus and response points could be quickly learned. For example, the precision of singing a tune, the match between a sung note and a correct note, develops from the automatic reinforcement of hearing one's own voice. This reinforcement is differential only to the extent that the singer can discriminate among the produced notes. Therefore, the simple training of a few notes would not be sufficient to condition a fine-grained repertoire for on-key singing. Based on the theoretical analysis of Holland and Skinner (1961), discrimination training among musical notes and produced notes would speed up the learning of accurate on-key singing.

This role of discriminated stimuli is illustrated by applied work in improving articulation of speech sounds (Holland & Matthews, 1963). Children who had speech difficulties with the /s/ sound were given discrimination training along this dimension. Observational results indicated spontaneous vocalizations of the correct speech sound during discrimination training and prior to actual production training. Since subjects had

learned to discriminate between correct and incorrect sounds, they were then able to adjust their produced sound to match the correct /s/ pronunciation. Once correct and incorrect /s/ sounds were discriminated, only feedback from a correct /s/ pronunciation would serve as reinforcement. This match between the proper sound and the produced or feedback sound becomes a reinforcer which can then maintain and continue to shape correct pronunciation.

The possible importance of discriminated feedback as it relates to continuous repertoires suggests the need for systematic research. However, no research has touched on this problem. In keeping continuity with previous research designs, several points of correspondence between the experimental stimulus and response continua should be trained; but in addition to binary, differential reinforcement (a reinforcer when correct and no reinforcer when incorrect), a feedback stimulus should follow each response. As in the above analysis of feedback, a comparison between the feedback and sample stimuli could provide a continuum of more precise reinforcement.

Such a continuum of reinforcement should facilitate speedy learning if certain other conditions are met. In the previous research, the new intermediate responses were never reinforced during training. Extinction of these responses may retard development of intermediate responses and, therefore, extinction might best be avoided if speedy continuous repertoire development is the objective. In addition, there typically has been no discrimination training of values from the stimulus continuum. If novel, intermediate stimulus values are functionally the same as the training values, then there is no reason to ever expect finer response mapping to new stimuli. Furthermore, without such discrimination, the feedback stimuli could not provide fine-grained differential reinforcement for a match between the feedback and the sample stimuli. Only when subtle variations in the produced stimuli are discriminated can this feedback provide the

automatic, differential reinforcement for correspondingly subtle variations in responses. The reinforcing precision of feedback stimuli is only as good as the discrimination of the feedback stimuli. Consequently, the establishment of these discriminative skills could be crucial for the rapid learning of a continuous relationship between stimuli and responses.

From these suggestions a clear demonstration of a continuous repertoire may be possible under certain optimal conditions. The following experiment sets up ideal conditions for the laboratory development of a continuous repertoire by first insuring discriminable feedback. In addition, extinction during training of intermediate, nontrained responses is prevented, as is overtrained, stereotyped responding. And finally, if a finer continuous repertoire than that which is trained will not emerge full-blown, but is instead characterized by rapid learning of each new point, then testing during extinction is inappropriate. To measure this rapid learning the present study looks at the acquisition of new stimulus and response points under continued reinforcement. Under these conditions, new, intermediate responses may quickly become controlled by intermediate, novel stimuli.

Method

Subjects

Thirty-six 5- to 6-year-old children from an urban school served as subjects.

Apparatus

The apparatus was a 20.3 cm x 40.5 cm x 23 cm black and yellow metal box. The upper front of the experimental box had a row of three 2.6 cm x 2.6 cm transparent plexiglass keys located 3.8 cm from the top of the box and 4.1 cm apart. On the lower front, 4.5 cm below the upper

three keys, was one long key, 2.6 cm x 30 cm. The upper three keys were hinged at the sides and had microswitches on the opposite side. Each microswitch was activated by the movement of the plexiglass key. The long key was a strip of glass with an electrically conductive surface (Nesa glass). The Nesa glass was etched into five 2.6 cm x 6 cm electrically distinct areas. An Eico Touch Switch, which was activated when the glass was touched, was connected to each of five areas. Behind each of the upper three keys and the five areas along the lower long key was a One-Plane-Readout Projector which projected the stimuli. All stimulus events and recording of data were automatically controlled by electromechanical equipment housed in another room.

The pretraining and training stimuli are illustrated in Figure 1.

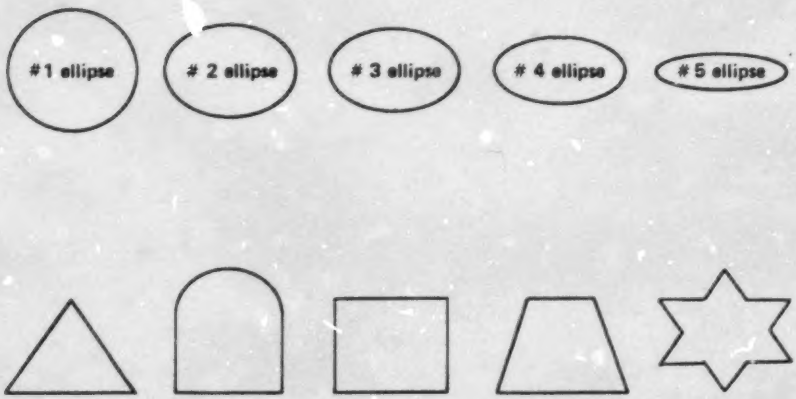


Figure 1. Stimuli used for pretraining and training. Progressively flatter ellipses served as the training stimulus dimension for all subjects, with these ellipses also serving as the pretraining stimuli for the prediscrimination group and the geometric shapes serving as pretraining stimuli for the nonprediscrimination group.

During training and testing, the experimental stimulus continuum for all subjects was ellipse height. From this dimension, five progressively flatter ellipses ranging from a circle to a nearly flat ellipse served as the experimental values. For pretraining, subjects received discrimination training of either these five ellipses (the prediscrimination condition) or, for control purposes, five nonelliptical geometric shapes (the nonprediscrimination condition).

Procedure

Subjects were escorted from a playroom to the experimental room. Each child was seated before the experimental box and told that during this game anytime they were right they would hear a bell chime and they would get an M&M. If all three experimental stages were not completed by the end of 30 minutes, then the subjects were asked to return the next day to complete the game.

Pretraining. Each child was assigned randomly to either the prediscrimination or nonprediscrimination group. At the beginning of each trial for both groups, one of five geometric shapes, determined by a randomized sequence wired on a stepper, was presented on the upper center key. For the prediscrimination condition these shapes were ellipses of varying heights (the length of the minor axis); for the nonprediscrimination condition the shapes were nonelliptical geometric forms. Subjects were instructed to touch the center picture which resulted in the presentation of the comparison stimulus on the right key while the standard stimulus remained on the center key and the left key remained blank. The comparison stimulus was either identical to the standard or was one of the other four stimuli. Subjects were told to touch the comparison stimulus if it matched the center stimulus. If the comparison stimulus was different from the standard stimulus, subjects were told to touch the blank left key

(see Figure 2a). A response to one of the side keys turned off both the standard and comparison stimuli and initiated a 3-second intertrial interval. If the response was correct, a bell sounded, an M&M was dispensed, and a new trial began with a new standard stimulus at the end of the intertrial interval. A correction procedure was used in which if any incorrect choices were made, the 3-second intertrial interval was initiated immediately and the next trial began with the same standard and comparison stimuli. After reaching a criterion of 8 correct responses out of 10, subjects began the next stage of the procedure.

Training. Both groups received identical training with three positions on the response continuum trained to three values from the ellipse continuum.

The errorless technique used was adapted from Touchette's (1971) errorless procedure. Touchette first establishes stimulus control by a salient cue stimulus. This cue stimulus is then superimposed over the positive stimulus (S+). Initially, cue stimulus onset occurs with the onset of the S+, but on successive correct trials, the onset of the cue is progressively delayed from the onset of the S+. The subject eventually begins to respond before the cue, thereby demonstrating a shift of control from this cue stimulus to the S+. When this shift occurs, the subject reaches S+, responding with few errors, if any.

The present study began this training with the random projection of one of three stimulus values (ellipse 1, 3, or 5) onto the upper center key. Subjects were told to touch this sample ellipse and then to find the matching ellipse which was now hidden somewhere behind the lower long window. Initially, there was simultaneous presentations of the sample ellipse and a red cue light on the appropriate corresponding area along the lower response continuum. Subjects were told that this red light tells them where the matching ellipse is hidden, but that they should try to "beat the

red light" during the game. The cue stimulus was manually delayed in increments of 1/2 second following each correct trial; after an incorrect trial the red light occurred 1/2 second sooner. When the subject touched any response area, the red light was turned off and a response-produced stimulus, the ellipse corresponding to the area touched, was projected onto that area for 2 seconds. If the subject touched the correct area, an ellipse matching the sample ellipse was projected onto that response area and a bell sounded while an M&M was dispensed. After an intertrial interval of 3 seconds, the next sample stimulus was projected. When an incorrect response area was touched, the projected feedback ellipse did not match the sample, and following the 3-second intertrial interval, the same sample stimulus was presented again (see Figure 2b). Subjects continued to respond according to the above procedure until they reached a criterion of 8 out of 10 consecutively correct responses without the cue light. Having reached this criterion, subjects from both the prediscrimination and non-prediscrimination groups were randomly assigned to one of two test conditions.

Testing with a learning measure. The rapid learning of stimulus and response points ordered along continua was gauged by comparing the learning of ordered stimulus and response points with the learning speed of separate stimulus and response points that have no ordered relationship. The present study made this comparison by training three points from the stimulus and response continua (S1-R1, S3-R3, and S5-R5) and then continuing to train stimulus and response points intermediate to these. The intermediate points either followed the trained order (S2-R2 and S4-R4) or reversed this order (S2-R4 and S4-R2). (See Figures 3a and 3b.) If conditions conducive to the rapid formation of a continuous repertoire were present, then learning the ordered, intermediate stimulus and response pairings would be facilitated. Any tendency to map responses along a continuum to stimuli along a continuum would interfere with the

Ordered Test

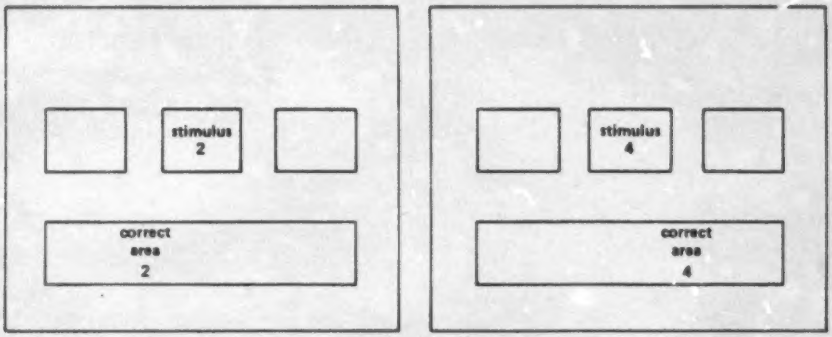


Figure 2a. The ordered test reflects ordered pairings of novel stimuli and responses (S2–R2) and (S4–R4).

Unordered Test

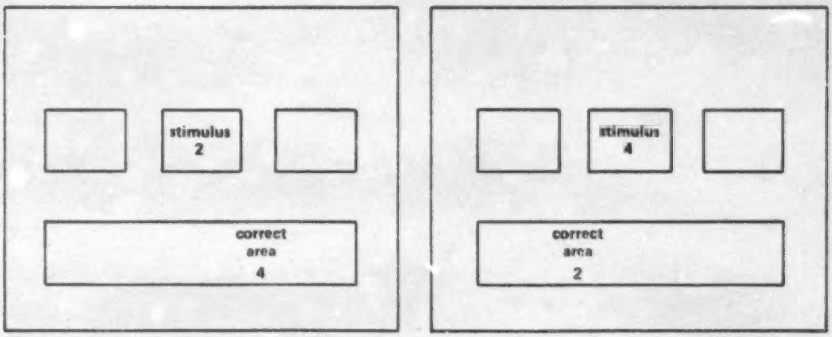


Figure 2b. The unordered test reflects reversed pairings of novel stimuli and responses (S2–R4 and S4–R2).

PRETRAINING

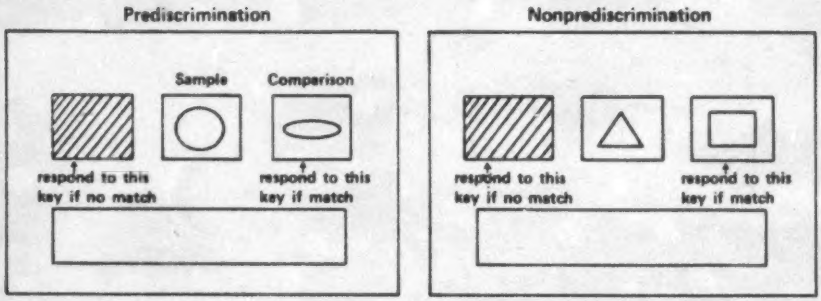


Figure 3a. Illustration of pretraining procedural conditions.

TRAINING

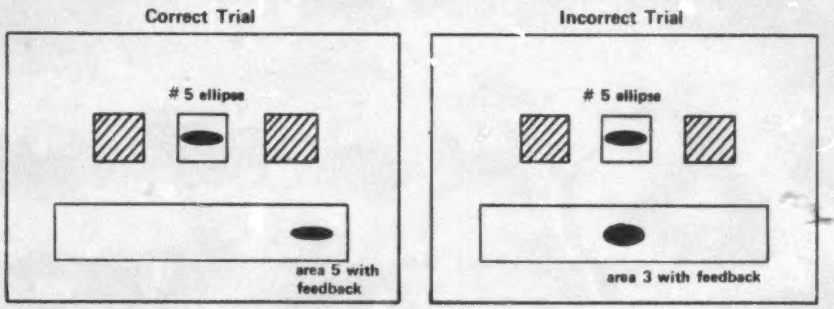


Figure 3b. Illustration of training trials. When the flat ellipse appears as the sample stimulus, a correct response to the end position generates the corresponding flat ellipse. An incorrect response to the middle position generates the corresponding ellipse for that area, but this ellipse does not match the sample.

acquisition of the unordered, intermediate stimulus and response pairs. On the other hand, if conditions necessary for the rapid acquisition of a continuous repertoire were not present, then the ordered and unordered tests would be of equal difficulty. The speed or ease with which the ordered problem is learned relative to the unordered test would then indicate the extent of continuous repertoire development.

Subjects began this continued learning task as an extension of the training sessions. At the end of the training stage, subjects were responding appropriately to stimuli 1, 3, and 5 without cue light superimposition. The cue light continued to be absent during testing, and all appropriate responses continued to be reinforced. The only change from conditions present at the end of the training stage was the introduction of two new stimulus and response points. Half the prediscrimination and half the non-prediscrimination subjects learned the ordered task in which responses to area 2 during stimulus 2 and area 4 during stimulus 4 were reinforced. The other half of the subjects learned the unordered task in which the stimulus and response correspondences were not continuous, where a response to area 2 during stimulus 4 and a response to area 4 during stimulus 2 were reinforced. The acquisition of the stimulus and response correspondences continued for both test groups until there was a block of 10 trials in which at least 5 out of 6 trials of the new intermediate test stimuli and 3 out of 4 trials of the three trained stimuli were correct.

Results

Pretraining Results

Overall, very few errors were made during discrimination training of the ellipse dimension. Of the 18 subjects receiving prediscrimination of the ellipses, all but two made less than 5 errors, and the other two subjects made 6 and 7 errors. Similarly, during discrimination training of

the irrelevant geometric figures, 15 of the 18 subjects made less than 6 errors, and the other three subjects made 8, 9, and 10 errors.

Training Results

Subjects' training performances for the three ellipse-response position points were analyzed to insure that any test differences were due to experimental variables and not to artifacts of sampling. Since all subjects received the same training, there should be no difference between errors to criterion or trials to criterion for the training performances. All subjects made very few errors during the cue-delay errorless training, with seven subjects making no errors. Only one subject was rejected for errorful performance by making more than 10 errors during errorless training. *T*-tests comparing group error means and trials to criterion showed there were no differences between the prediscrimination and nonprediscrimination groups or between the ordered and unordered groups during training. This homogeneity of group training performances allowed any later differences in test performances to be attributable to experimental variables and not to uncontrolled group differences. If, for example, the ordered test was learned more quickly than the unordered, then this test difference would reveal a real difference between the tests and not a difference resulting from the ordered-test subjects being pre-experimentally faster learners than the unordered-test subjects.

Test Results for Nontrained Stimulus

Individual data. Individual results for the ordered and unordered tests are shown in Figures 4, 5, 6, and 7. Each of these frequency graphs shows the response locations for the test ellipses S2 and S4. Since the training ellipses, S1, S3, and S5, continued to control the appropriate trained responses during this testing period, individual portraits of the controlling relations for these stimuli were unnecessary. As an example

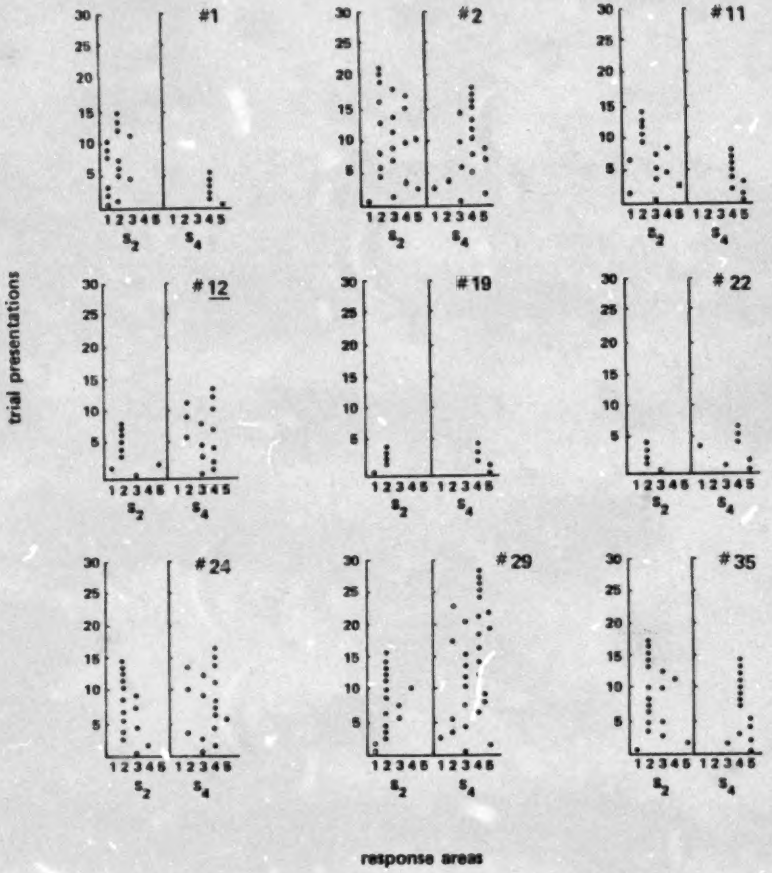


Figure 4. Individual test data for subjects who received prediscrimination training and the ordered test.

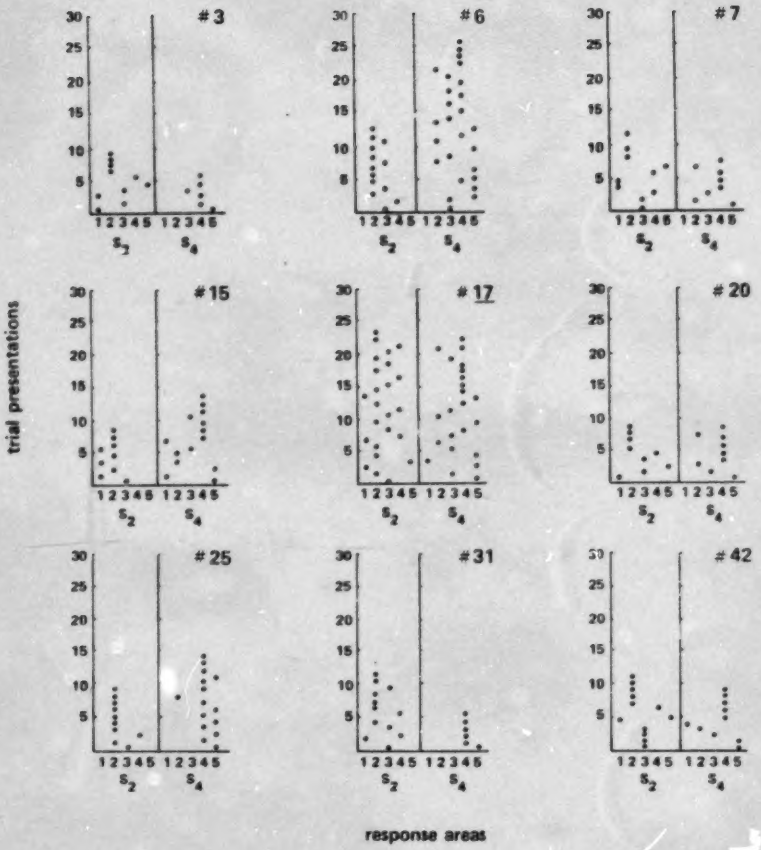


Figure 5. Individual test data for subjects who received no prediscrimination training and the ordered test.

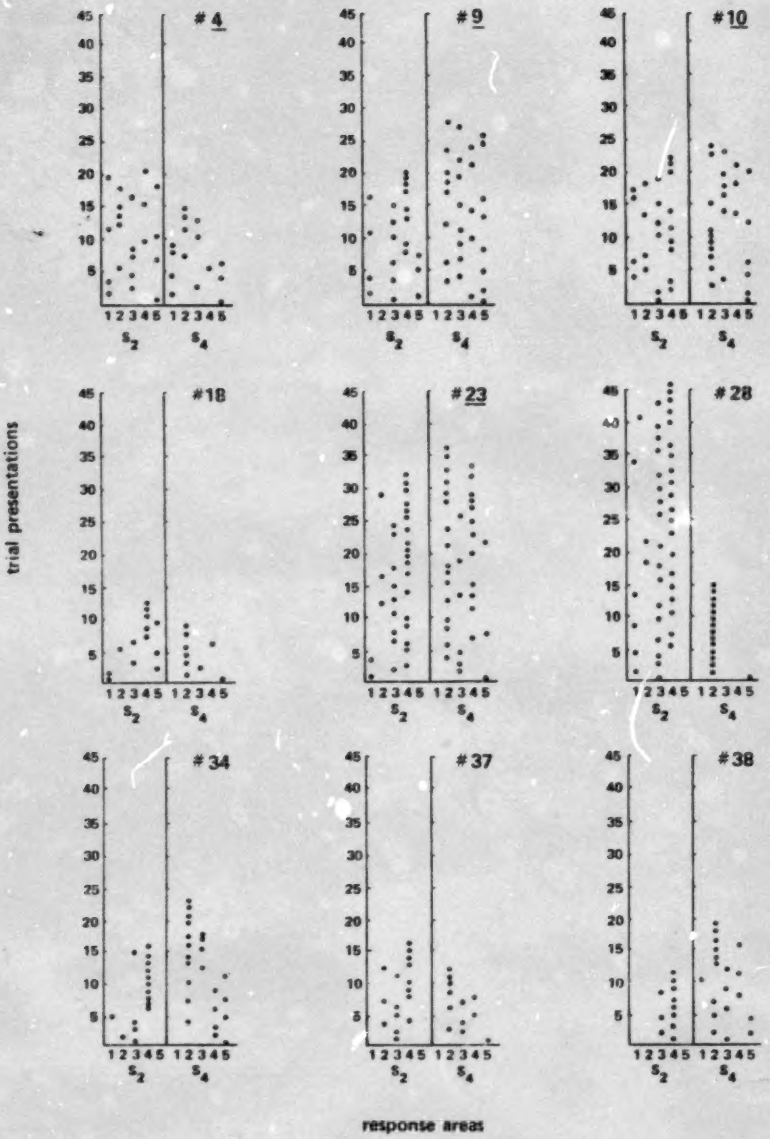


Figure 6. Individual test data for subjects who received prediscrimination training and the unordered test.

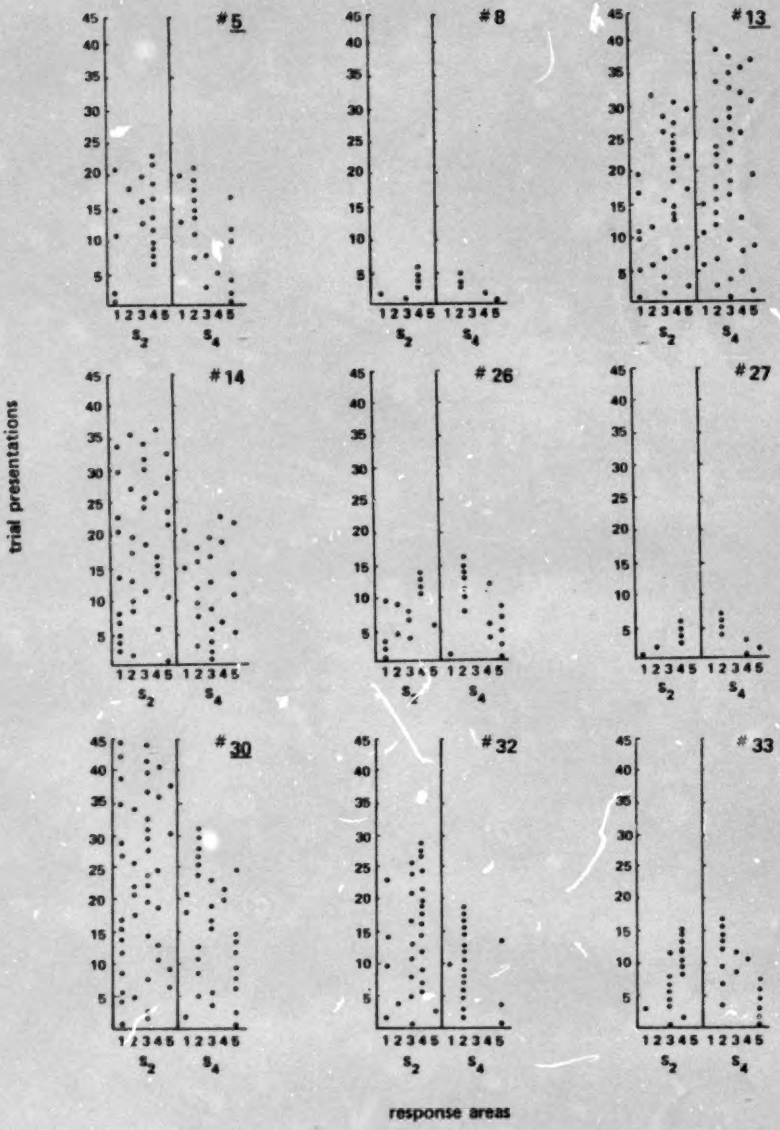


Figure 7. Individual test data for subjects who received no prediscrimination training and the unordered test.

of plotted response topographies for S2 and S4, refer to subject #19 (Figure 4), who received the ordered test with reinforcement contingent on a response to area 2 for S2 and area 4 for S4. On the first presentation of S2, this subject responded incorrectly to area 1. This event is represented on the S2 graph, where it is plotted at the coordinates of area 1 on the abscissa and stimulus presentation 1 on the ordinate. On the second presentation of S2, this subject mapped correctly to area 2, which is represented by a point at the intersection of area 2 and presentation 2. On the first and second trials of S4, #19 responded to area 5 both times, but corrected himself by the third trial with a response to area 4. These results are recorded by plotting on the S4 graph above area 5 at stimulus presentation 1, above area 5 at stimulus presentation 2, and above area 4 at stimulus presentation 3. The remaining test stimuli trials show there were no further errors. By counting the points that vary from the appropriate areas 2 and 4, an error count can be made; in this instance subject #19 made 3 errors. This dispersion of dots from the appropriate positions indicates the number of errors to criterion for each subject.

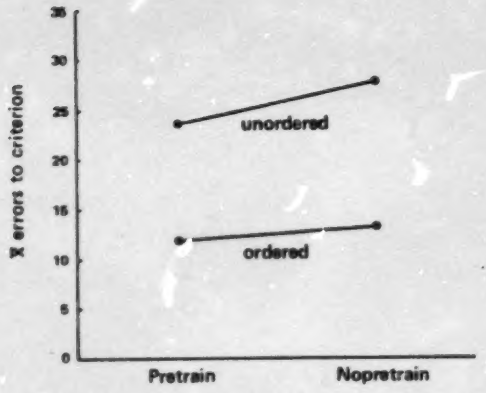
Inspection of all the graphs reveals variability between subjects, as well as a lack of any apparent difference between prediscrimination and nonprediscrimination (compare Figure 4 with 5 and 6 with 7). For example, for the ordered test, regardless of prior experimental training, there were few errors except for the two prediscrimination subjects #29 and #2 and the two nonprediscrimination subjects #17 and #6. This same similarity across prediscrimination and nonprediscrimination groups holds for the unordered test where the nonprediscrimination subjects #5, #13, #14, #30, and #32 all show numerous errors to criterion and this dispersed response pattern is also evident for a number of prediscrimination subjects, #4, #9, #10, #23, #28, and #34.

Although pretraining had no apparent effect, there is a difference between test conditions. The unordered test (Figures 6 and 7) resulted in more errors and more trials to criterion than did the ordered test (Figures 4 and 5). In fact, 8 of the 18 subjects who had the unordered test were unable to reach test criterion, whereas only 2 of those who had the ordered test failed to complete it. (In Figures 4, 5, 6, and 7, the subject number is underlined to indicate those who never reached criterion.) Thus, it appears that the unordered, noncontinuous test problem was more difficult than the ordered test, regardless of prior experimental discrimination training.

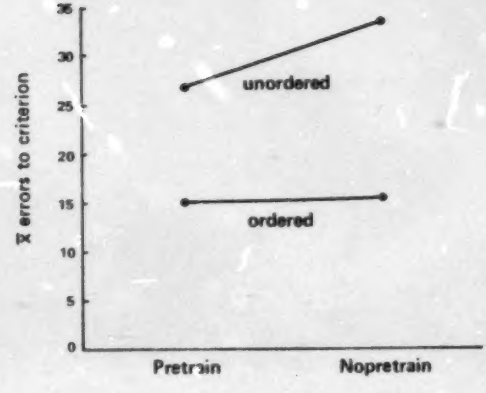
Close examination of the individual graphs also reveals that during early test trials, responses to the trained positions closest to the intermediate position were most typical. On the first S2 trial, 92% of the subjects responded to the training positions 1 and 3. Of the 36 subjects, 19 responded to area 1, 14 to area 3, only 2 chose position 5, and 1 touched area 4. On the first S4 trial, 97% of the subjects responded to the training positions 3 and 5, with 27 subjects responding to area 5, 8 to area 3, and only 1 subject showing early trial mapping to area 4.

When responding finally broke from these trained response topographies, there was no immediate tendency to map responses along a continuum. There was no tendency for an area 2 response to S2, nor for an area 4 response to S4. Specifically, the first response to a nontrained area during S2 was area 2 for 58% of the subjects and area 4 for 42%. Similarly, during S4, the first response after the break from training topographies was to area 2 for 50% of the subjects and area 4 for the other half. Clearly, response mapping or an orderly correspondence between novel stimulus and response points did not emerge full-blown without training.

Mean error data. The data for errors on test stimuli were reduced to group means and plotted to indicate average trends. In Figure 8 the



Test Stimuli 2 & 4



All Stimuli 1,2,3,4, & 5

Figure 8. The mean number of errors after the introduction of novel stimuli. The difference between the ordered and unordered tests appears significant across both prediscrimination and no prediscrimination. This relationship is graphed for the test stimuli only and for all the stimuli during testing.

effects of pretraining and test condition corroborate what the individual data revealed. Pretraining had no differential effect, but the unordered test produced more errors and, therefore, was more difficult to learn than the ordered test.

Analysis of variance. A two-way analysis of variance on errors to test stimuli S2 and S4 supports the above conclusions. Neither pretraining nor the interaction of the variable with the two different test conditions showed even a glimmer of significance, while the analysis of the difference between the two test conditions proved to be significant at the .01 level of probability.

Test Results for All Stimuli

Summary graphs of the testing data show the percentages of total responses at each response position during each of the five stimuli. Each point indicates the degree of control by one of the five stimuli over responding to that position. In Figure 9a these percentages are plotted for all test trials. In order to trace the development of stimulus control by the new intermediate test stimuli S2 and S4, the first 15 trials were plotted in Figure 9b for comparison with graphs of all test trials.

These graphs show the continued stimulus control by the training stimuli, especially the end values. For example, 100% of the responses during S1 were at the appropriate position 1, and 95% of the responses during S5 were at the appropriate position 5 (Figure 9a). Across all the graphs, S3 demonstrates less control to its corresponding response position than the end training stimuli, as would be expected based on the similarity S3 has with both intermediate test stimuli S2 and S4.

Since the unordered test took longer to learn than the ordered, there is evidence that regardless of experimental pretraining, subjects were able to learn a continuous repertoire more rapidly than five unrelated

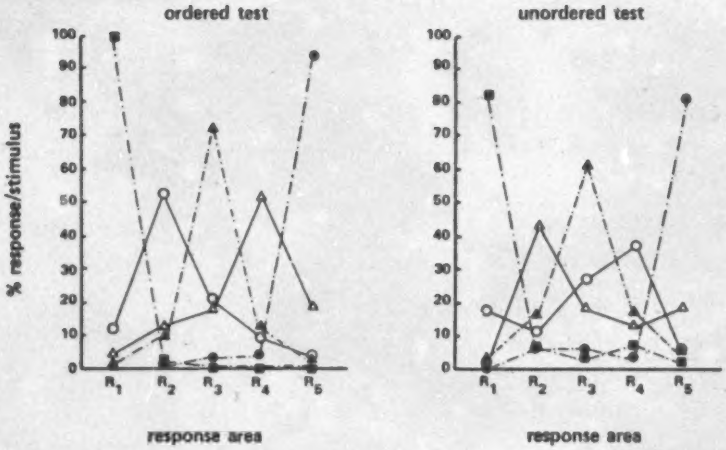


Figure 9a. For all test trials, functions for each of the stimuli showing percentage of the responses to each position.

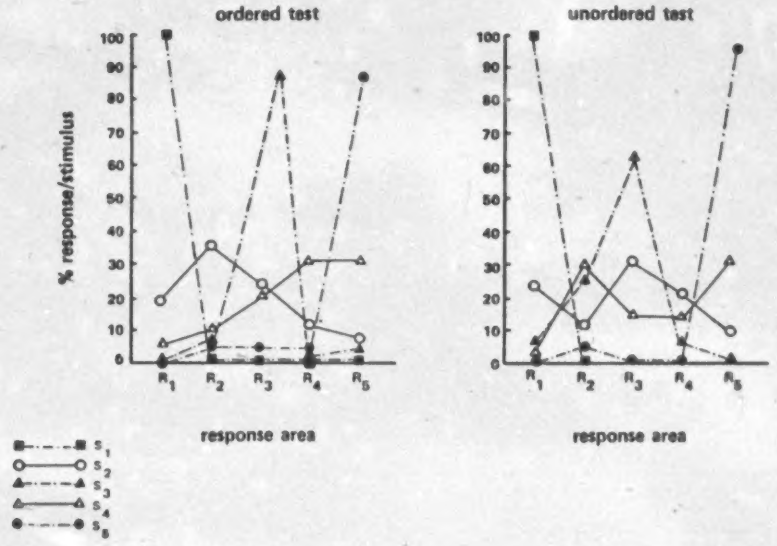


Figure 9b. For the first 15 trials, functions for each of the stimuli showing percentage of responses to each position.

stimulus and response pairs. A comparison of early test trials may elucidate reasons for this difference in learning rate. One might have expected that the delay in learning the unordered problem is due to a tendency to order responses along the stimulus continuum. The early, unordered test results compared to the ordered test (Figure 9b) shows only that the unordered produced more persistent responding to training positions. Specifically, in the first 15 trials the unordered problem shows the greatest proportion of responses during S2 to area 3 and during S4 to area 5; whereas the ordered problem, even within the first 15 trials, is learned more quickly with, for the most part, the new stimuli, S2 and S4, controlling appropriate intermediate responding. These data again indicate that mapping responses to a stimulus continuum must be learned, and that it is easier to learn a response order in accordance with a stimulus order rather than separate, noncontinuous stimulus and response pairs.

Discussion

When conditions are right, a fine-grained or continuous repertoire develops rapidly. The right conditions seem to be presence of discriminated feedback and limited extinction to new points along the stimulus and response continua. The present data showed that after errorless training of a few stimulus and response points with discriminated dimensional feedback, subjects were able to learn new stimulus and response points that were continuously ordered (S2-R2 and S4-R4) with fewer errors and thus more rapidly than subjects who learned new stimulus-response points that were unordered (S2-R4 and S4-R2). This difference demonstrated a continuous repertoire since the ordered points should be easier to learn to the extent that conditions conducive to a continuous repertoire were present.

The data suggested that each new point in a continuous repertoire must be trained. After training three responses to three stimuli from stimulus and response continua, early trials of the new intermediate stimuli failed

to show intermediate responding. Only after reinforcing intermediate responses in the presence of intermediate stimuli did this finer response mapping to the stimulus continuum develop.

Intuitively, it is compelling to expect the emergence of intermediate responding to intermediate stimuli after training a few representative points from stimulus and response dimensions. However, the present findings are most compatible with the usual interpretation of stimulus control results when a single response is used. When a stimulus is varied, as in tests of stimulus generalization, the rate of the response may decrease from the rate found in training; but there has been no provision in stimulus control theory for the response to vary as the stimulus varies from the original trained value. This study, as well as earlier studies assessing intermediate responding, provoke no revision of the traditional view of stimulus control.

The focus of this study can be contrasted with previous attempts to show a continuous repertoire. Earlier research addressed itself to measuring the extent to which nontrained, intermediate stimulus and response associations were learned during original training of a few representative points from stimulus and response continua. Testing in extinction then would show intermediate responding to intermediate stimuli if it had been acquired without explicit training during original training. But none of the research found this emergence of fine-grained continuous repertoires; instead, intermediate stimuli evoked only those topographies that had been directly trained. Given that a fine-grained, continuous repertoire must be trained, the present research asked a different question--under what conditions would the acquisition of a continuous repertoire be rapid? With this focus, a learning test or testing with reinforcement was necessary. The learning test showed that with an errorless training procedure and dimensional feedback, ordered stimulus and response points are easier to learn than unordered ones. Since all continuous repertoires are

characterized by the correspondence of ordered stimulus and response points, or the orderly scaling of responses to a stimulus continuum, what may be learned in training is a concept of stimulus and response order which, along with dimensional feedback for adjusting responses, speeds up later learning of new points from the continua.

Even though the present study successfully demonstrated the rapid learning of a continuous repertoire, it failed to determine the extent to which discrimination training of the stimulus continuum alone affected acquisition rate. The data show that pretraining had no differential effects. Subjects without discrimination training learned the ordered test as easily, and the unordered test with the same difficulty, as those subjects with prediscrimination training. Since the difference between the ordered and unordered tests indicates continuous repertoire development, a continuous relationship was learned rapidly, even without relevant prediscrimination training. But pretraining of values from the stimulus continuum may still be a necessary condition for learning a continuous repertoire since it is apparent from the few pretraining errors that these ellipse values were already discriminated. If the discrimination had been more difficult, then perhaps differential pretraining would have resulted in rapid learning of new points for the prediscrimination group only.

The present study emphasizes the potency of prediscrimination training under optimal conditions for rapid learning, that is, under errorless training and dimensional feedback conditions. Consequently, beyond pretraining, these other two conditions, to varying degrees, may affect continuous repertoire development. Since extinction of intermediate responses and extensive training may hinder the later learning of intermediate stimulus and response points, the present study lessened this possibility by using errorless training. It is hardly surprising that earlier research failed to show appropriate new responses during tests with novel stimuli because these responses were extinguished during training and extensive training

anchored responses to trained topographies. In the present study, errorless training, for the most part, prevented errors during training to intermediate responses, as well as speeded up training. With no extinction of novel, intermediate responses and a reduced tendency for stereotyped responses through quick training, the probability of intermediate responding was not reduced and, consequently, later learning of new, intermediate values could occur more rapidly. However, errors may in fact significantly facilitate learning if discriminable feedback is provided. In the present experiment if learning had proceeded with errors and each error had produced dimensional feedback, then under these conditions subjects could have "learned from their errors." They could learn how wrong or how right each response was and adjust subsequent responding accurately. The significance of this kind of feedback should not be overlooked, yet its function in the experimental analysis of fine-grained repertoires remains unexplored.

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